

Evaluation of the impact of net neutrality on the profitability of telecom operators

A game-theoretic approach

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Abstract - Net neutrality is defined as the concept in which Internet service providers are obliged to treat all data streams equally, independent of which application, service, device, sender or receiver is involved. They are as such forbidden to block, throttle or alter data traffic over their networks. The current debate about net neutrality raises important questions about if and how it should be implemented by law. This research summarizes the current regulations regarding net neutrality in the EU and US and finds significant differences, as well as specific cases where operators breached (or tried to breach) the concept of net neutrality. A case study about video on demand is used to analyze both these violations and certain approaches under net neutrality in order to see which scenario offers the greatest benefits, both from an operator's, as well as from a regulator's perspective. The results are computed using a game theoretic approach and from these results recommendations are subtracted that can be presented to regulators. The study finds that net neutrality can be enforced by law to prevent the decline of competition and innovation on the market.

Keywords - net neutrality, game theory, telecommunications, congestion, video on demand, techno-economic analysis

1 An introduction to net neutrality

The Internet is an ubiquitously available platform for information, entertainment and communication. Over the years, the position of ISPs (Internet Service Providers) has become one of an essential gatekeeper, which puts them in control of the information flow on the web. Net neutrality (NN) is defined as the concept in which ISPs are obliged to treat all data streams equally, independent of which application, service, device, sender or receiver is involved. They are as such not allowed to block, throttle or alter data traffic over their networks. With the rise of Over-The-Top (OTT) applications and providers, a significant amount of Internet traffic is no longer fully controlled by the ISPs. The increase in Internet traffic that these OTT applications bring, demands for upgrades to the network, but does not return a direct revenue for the ISPs. This issue lies at the heart of the current debate about net neutrality and raises important questions about if and how it should be implemented by law [1].

1.1 US regulations

The Federal Communications Commission (FCC) tried in various ways to impose a certain level of NN to the US telecommunications market. This section presents a brief overview of the developments of the regulations in the US.

The Communications Act of 1934 divided the electronic communications into different types of services. The ones that matter to the Internet are information services (Title I) and telecommunication services (Title II). Every service categorized as a Title II service is viewed as a common carrier, and can hence be regulated by competition law and the FCC. Title I services stand in sharp contrast, as the FCC there has little or no regulatory power. Originally, the backbone ISPs' services were regarded as information services, but the access ISPs services were categorized as telecommunication services. As a consequence of deregulation measures, this categorization changed in 2005, by classifying Internet access, when bundled with Internet services, as an information service. As such, the access ISP market was also left fairly unregulated [2].

Following some specific discriminatory practices (see also section 1.3), where the rulings of the FCC were found out of scope (the FCC cannot regulate information services), the FCC decided to follow a different path. In 2010, they published the Open Internet Ruling, as an attempt to implement stricter NN rules for the fixed broadband market. This proposal was overturned by the courts, which led to long legal discussions between the FCC and the affected operators. In February 2015, finally, the lingering uncertainty was ended when the FCC adopted "strong, sustainable rules to protect the open Internet" [3]. In short, the rules can be summarized in three different parts [4]:

- *No Blocking*: ISPs may not block lawful content, applications, services or non-harmful devices, subject to reasonable network management.
- *No Throttling*: ISPs may not impair or degrade lawful content, applications, services or non-harmful devices, subject to reasonable network management.
- *No Paid Prioritization*: ISPs shall not accept payment (monetary or non-monetary) to set up “fast lanes” for specific content.

These rules apply to both fixed and mobile broadband for residential, commercial purposes, known as “broadband Internet access services”. Hence, enterprise services, virtual private network services and hosting or data storage services are excluded. Furthermore, the broadband Internet access services are now classified under Title II, albeit regulated using a “light-touch approach” (excluding unbundling the last mile, tariffing, rate regulation and cost accounting rules).

1.2 EU regulations

In the EU, NN has not attracted a lot of attention until 2009, most probably because no clear examples of critical NN infringements were visible until then. The growing number of regulatory reforms in the USA, Japan and Canada, and the growing number of consumer complaints about ISP malpractices made the NN debate emerge in the European Commission [5]. In contrast to the US, Europe consists of several separate telecom markets, each regulated by its own National Regulatory Authority (NRA).

In 2009, the European Commission introduced a new regulatory framework for electronic communications. In this framework the first real NN directives were included. These directives concerned [6]:

- Transparency about traffic management
- Facilitation of end user switching between ISPs
- Empowerment of the NRAs to impose a minimum Quality of Service (QoS), if necessary

In September 2013, the EC proposed a draft version on new regulations concerning the European single market for electronic communications. These regulations try to harmonize the electronic communications market, therefore also the NN regulations. This proposal is often referred as a middle way solution since it enables operators to prioritize specialized services, but preventing ISPs from blocking or throttling all types of content. This prioritization is furthermore only allowed if it does not degrade the QoS of other services. After adapting a few parts of the proposal, e.g. making the definition of specialized services stricter, the European Parliament adopted, on the 3th of April 2014, this proposal in a first reading [7]. This adoption by the Parliament however does not yet guarantee the approval of the proposal, as lawmaking in the EU

is complicated by the three-way dance between the presidency (Latvia currently), the European Parliament and the European Commission.

The current draft regulation [8] still focuses on the “end-users’ right to access and distribute content of their choice”, as well as “ensure that companies that provide Internet access treat traffic in a non-discriminatory manner”. However, and this in sharp contrast to the US-adopted rule on paid prioritization, the current EU proposal allows for “agreements on services requiring a specific level of quality”.

1.3 Recent examples of net neutrality breaches define the research scenarios of this paper

The current legislative and regulatory debates about net neutrality clearly show that there is no consensus if and to what extent net neutrality should be imposed upon ISPs. This paper aims at investigating, in a quantitative way, how the involved telecom providers and the market in general can be influenced, when NN obligations or non-NN conditions are imposed. This section defines different research scenarios, based on net neutrality obligations and recent events where operators proposed (and sometimes implemented) measures conflicting with net neutrality. Please note that the specific scenario of total blocking of an OTT application will not be taken into account: no market share can be gained by the OTT, so no competitive game can be played.

1.3.1 Scenario 1: Basic net neutrality

The first scenario is a benchmark scenario; the network is assumed to be saturated in the beginning of the study period, each increase in traffic demand will result in congestion problems. As network neutrality is assumed, bandwidth is evenly distributed across players.

1.3.2 Scenario 2: Network upgrade under neutrality

In the second scenario, NN is again assumed, thus distributing bandwidth evenly across players, but congestion problems are lifted because the ISP will upgrade its network. This network upgrade is modeled following the network upgrade performed by Telenet (the Flemish cable operator), who increased bandwidths by node splitting [9].

1.3.3 Scenario 3: Service access fee

By installing Deep Packet Inspection (DPI) equipment, the ISP is able to detect the different traffic flows for different applications. If the use of specific OTT applications is identified, the ISP can charge the end user an extra fee for using these services over its network. This scenario is based on the proposal of the Dutch ISP KPN to charge customers extra for the use of Voice over IP (VOIP) and Instant Messaging (IM) applications [10]. KPN showed in 2011 major losses suffered by the emergence of

applications such as Skype and WhatsApp, which it wanted to counter by introducing new tariffs in which customers would pay extra to use these applications. In response there was a motion voted by parliament to include net neutrality into law, making the Netherlands one of the first countries to have an explicit net neutrality law. Another, very similar, example can be found in Spain, where the ISP Yoigo wanted to charge extra for the use of Skype [11].

1.3.4 Scenario 4: Dominant ISP

This scenario is based on the case of Deutsche Telekom, the German ISP, who announced in 2013 that they switched from unlimited access to fixed data caps, whereby traffic generated by DT's own services would not count (or not fully count) towards these data caps [12]. Deutsche Telekom argued that a clear distinction must be made between net neutrality and free Internet: DT's television service was paid for separately, hence did not need to be counted in the Internet cap [13]. In the end, a court ruling prevented the action.

Other examples of ISP dominance can be found in the US and Canada [14]. The US ISP Comcast deliberately slowed down the Peer-to-Peer application BitTorrent, in both peak and low demand hours. Bell Canada slowed down the Peer-to-Peer traffic of its own customers during peak hours, but decided to also apply the throttling on the traffic of the virtual ISPs, because congestion problems were not sufficiently solved. The Canadian regulator here allowed the network management because Bell Canada could prove that the freed bandwidth was used for other time-sensitive applications, and network management for all ran ISPs alike.

The fourth scenario studied in this paper assumes that the ISP will prioritize his customers first, and allocate only what is left to the OTT customers. This will of course result in huge congestion problems for the OTT. As in the third scenario, DPI equipment is needed for network management and traffic recognition goals.

1.3.5 Scenario 5: Preferential Distribution Fee

The fifth and final scenario is based on the creation of a "fast lane", to which customers paying a higher fee are allocated. As such, those preferential customers will receive higher capacities for their services. The OTT can choose to buy any remaining capacity on this fast lane for the same fee. Normal customers will suffer more congestion. This scenario can be compared to AT&T's aspirations to give preferential treatment to Google's data at a higher price [15].

2 A game-theoretic model to simulate the outcome for operator and regulator

In order to evaluate the effect of the above-described scenarios on both the outcome for the operators (ISP and OTT, in terms of Net Present Value – NPV) and for the regulator (in terms of market uptake), a game-theoretic approach is combined with a market model. This section will describe the different calculation steps of the model in more detail, and will provide an overview of the parameters used.

2.1 Insights in the modeling approach

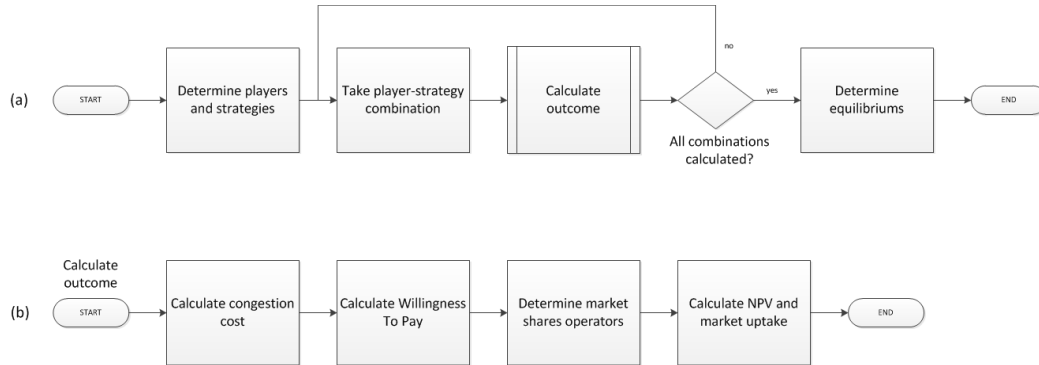


Figure 1: Overview of the game-theoretic model

As shown in Figure 1(a), each scenario requires to determine the players (one ISP, one OTT in the case of this paper) and their respective strategies (e.g. charge high or low price). For each combination of strategies, the outcome for the market should be determined (Figure 1(b)). Afterwards, game theory can be used to determine the equilibriums of the game, which indicate the preferred strategies of both players in a competitive setting. This section will explain the different steps of the modeling approach in more detail.

For each scenario, **players and strategies** need to be determined. The players are the same for each scenario: the market consists of one ISP and one OTT. Both players have the same choice of strategies: they can set a high VOD or a low VOD price.

For each player-strategy combination, the **outcome in terms of NPV and available market** need to be calculated. A first step in this process consists of calculating the **congestion cost**. In this paper, the congestion cost is modeled as an artificial price increase that reflects the lower degree of customer satisfaction. The amount of congestion is calculated using an exponential function that depends on a comparison between the needed bandwidth per person and the available bandwidth per person. This amount of congestion is scaled to a cost between zero (available bandwidth equals needed bandwidth) and double the normal VOD price as a maximum point (available bandwidth is zero). This congestion cost can then be used to determine the

Willingness to Pay by comparing the normal VOD price to the “actual” VOD price, which includes the congestion cost.

In a next step, the market model must determine the **market shares per player**, as the number of VOD customers each player serves directly impact the players’ cost and revenue structure, and hence their NPV. The different calculation steps of the market model are shown in Figure 2. The distribution of the customers generally occurs in four phases [16]:

1. The total number of customers that will subscribe to one of the players must first be calculated. This number depends on the determined Willingness to Pay (determined above) and the price elasticity of the VOD market. This first step thus calculates the overall growth (or shrinkage) of the VOD market.
2. Next, from this total market, the free market is derived. The free market represents all customers that are “free” to choose a new provider, and is calculated as the sum of the new customers (of course only in case of a growing market) and the churning customers (those that change provider).
3. By defining the market division, the free market can be distributed to the different offers, resulting in the calculation of the market shares for all offers. There are different strategies for defining this market division. The most well known probably is ‘The Winner Takes All’. However, in reality, it hardly ever is the case that one supplier captures the entire free market. It will most likely be the case that the best offer captures most of the market, but all other offers can still attract market share. Still, the demand of each service or good will still be impacted by the price of the other offers. In economics, such an effect is indicated by the cross-price elasticity of demand.
4. In a final step, the relative market division can be used to distribute all free customers among the players, thereby determining each player’s customer base.



Figure 2: Overview of the calculation steps in the market model

A final step in the calculations for each strategy combination, is determining the **outcome per player by calculating its NPV or actual market uptake**. These parameters were chosen to represent the operators’ perspective (NPV, i.e. maximizing profit) and the regulator’s perspective (market uptake, i.e. maximizing the number of satisfied customers). The NPV is calculated based on both costs and revenues for both players, which depend on the chosen scenario (see section 3). The actual market uptake is calculated as the sum of all market shares of all players in each year.

Once the outcome for all strategy combinations has been calculated, game theory can be used to **determine the equilibriums**, i.e. the best strategies for both players [17]. The model in this paper calculates both Nash and Pareto equilibriums. A Nash equilibrium is defined as a situation in which no player can gain by unilaterally changing its strategy. A change to a different strategy combination making at least one player better off without making another actor worse off is called a Pareto improvement. When no Pareto improvements can be made from a given strategy set, the set is Pareto optimal or efficient.

2.2 Overview of used input data

The results that will be discussed in this paper are based on a case study for the Flemish market, in which the Belgian cable operator Telenet (ISP) competes with the new entrant Netflix (OTT) for the VOD market. The used parameters can be found in Table 1. The subscription fees reflect the difference in VOD charges for Telenet and Netflix (the OTT subscription fees are significantly lower), the Internet charges are based on a Telenet's basic Internet offer. As we assume the OTT is just entering the market, its initial market share is 0%, while the ISP holds the entire available market at the start of our study (100%).

Table 1: Overview of parameter values for the Flemish case study

Parameter	Value
Number of households (Flanders)	2,083,828
Needed bandwidth for VOD	4.5Mbps
Subscription fee for Internet	€300 per year
Subscription fee for VOD (OTT)	€108 per year
Subscription fee for VOD (ISP)	€240 per year
Price elasticity VOD market	-1,39
Cross-price elasticity VOD market	1,08
Churn in VOD market	35% per year
Start penetration VOD market	40%
Start market share in VOD market (ISP)	100%
Start market share in VOD market (OTT)	0%
Service access fee	10% of VOD subscription fee
Operational expenses for access network (ISP)	€94 million per year

In each scenario, both players can assume strategies based on pricing: they can set a high or a low price. Given the difference in price setting in the real market, this paper makes the assumption that the low price for the ISP equals the high price for the OTT, and sets this price at the average of both realistic prices (€174).

For the specific case of DPI equipment installation, the cost for this specific equipment is calculated using an ECMN (Equipment Coupling Modeling Notation) model [18]. The different cost inputs can be found in Table 1.

Parameter	Value
Processor	€853
Memory chip	€74
Switch manager processor	€58
Ethernet multilayer switch	€5400
Chassis	€7700
Rack cabinet	€551
Technician	€20 per hour
Energy cost	€900 per year

3 Comparing the scenarios on Net Present Value and market uptake

After having detailed the model and the case under study, this section will describe the results for the different scenarios identified in section 1.3. These results indicate the preferred strategies for both ISP and OTT operators in the different scenarios, as well as the preferred outcome for the market (and hence the regulator). In a first section, the results of the benchmark “basic net neutrality” scenario will be discussed in detail, after which the following scenarios will be compared to this benchmark.

3.1 Basis net neutrality

This scenario is characterized by net neutrality without network upgrades: the available bandwidth is evenly distributed among ISP and OTT customers, but the limitations of the network lead to sharp increases in congestion, hence congestion cost. The game matrix outcome for this scenario is shown in Figure 3. The Nash equilibrium for both the NPV and the amount of customers are shown in grey, while the Pareto equilibriums are represented in bold. The high prices are indicated by the letter ‘H’, the low prices by ‘L’.

		ISP	Basic net neutrality			
			H		L	
OTT	Net present value	H	€ 1.180.403.549	€ 238.821.632	€ 1.061.502.664	€ 238.688.488
		L	€ 1.131.206.376	€ 255.530.741	€ 1.028.475.470	€ 260.859.049
	Percentage of customers	H	22,16%	14,40%	28,56%	14,40%
		L	18,77%	24,31%	25,67%	24,70%

Figure 3: The game matrix for the basic NN scenario shows different equilibriums for the operators’ and the regulator’s goals

The Nash equilibrium for the NPV shows that, for maximizing both players' profit simultaneously, the ISP will opt for the high price, the OTT for the low price. This can be explained by revisiting the start assumptions: the ISP starts the competitive game in a monopoly position (controlling the entire available market), thus gains the maximum number of revenues by charging the highest price. On the other hand, the OTT setting its price as low as possible results in a maximum attraction of free customers. The amount of customers the OTT gains by following this strategy increases his revenues more than adopting a higher price and attracting fewer customers. This monopoly start assumption also explains the higher absolute NPV for the ISP.

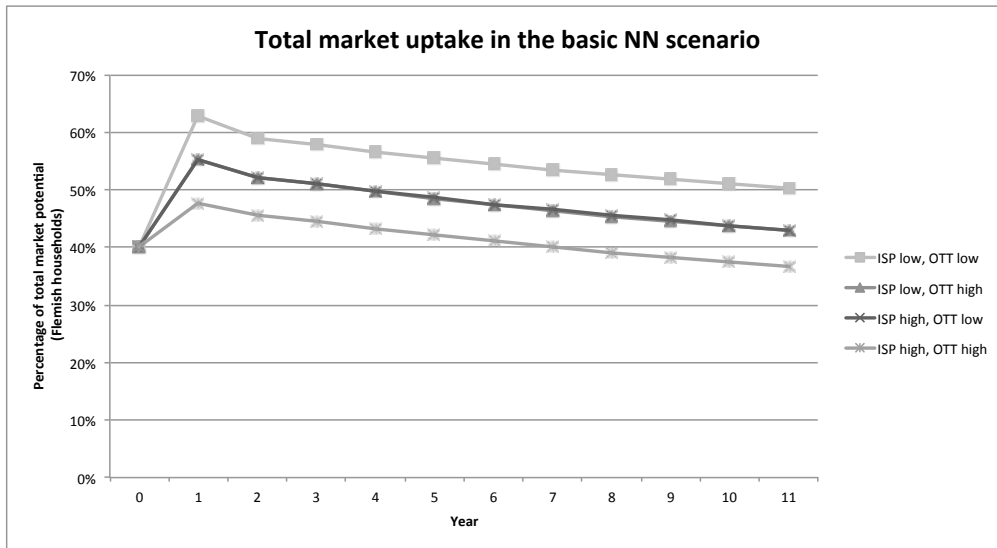


Figure 4: Customer distribution under basic net neutrality, in the NPV equilibrium where the ISP sets a high price and the OTT assumes a low price

When investigating the customer distribution and the effect of congestion, Figure 4 shows that the strategy combination that leads to the NPV equilibrium has a negative effect on the overall market uptake. By charging the highest price, the ISP will achieve the highest NPV on a period of 10 years, but loses each year all free customers to the OTT. As such, the high-price strategy taken by the ISP can be good in the short run, but the increase in congestion (and hence total – artificial – VOD subscription fee) will in the end lead to an over-expensive offer. Although the overall trend in market uptake for this scenario is decreasing, the first year gives an increase in the total market uptake. This can be explained by the fact that the average price for the VOD offer is lowered when the OTT player enters the market (see subscription fees in Table 1).

The uptake-maximizing equilibrium (from a regulator's perspective) is achieved when both players assume their lowest price. The reasoning behind this result is clear: as

the congestion significantly increases the subscription fees, the only way to reach as many customers as possible (offer a subscription below or equal to their Willingness to Pay), is to limit the charged prices. This impact is shown in Figure 5.

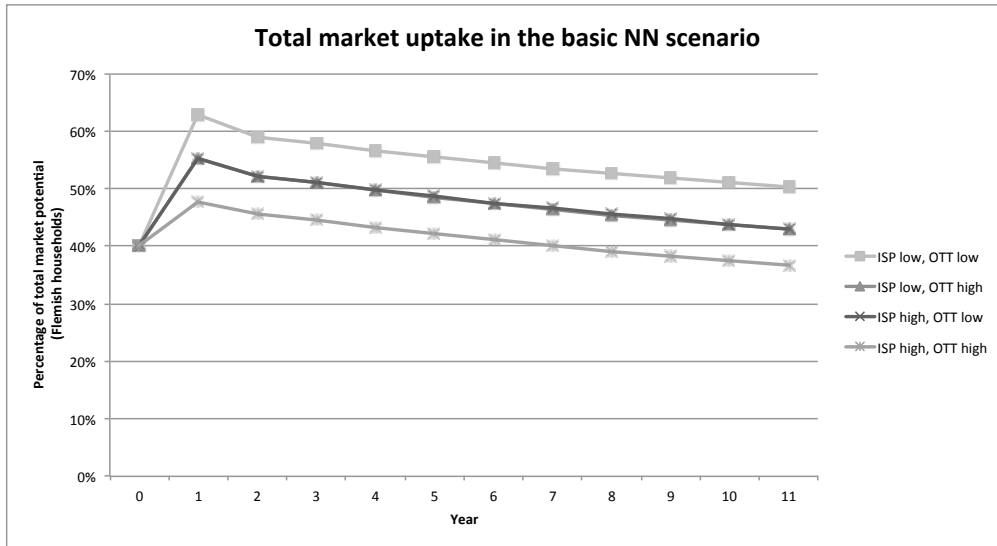


Figure 5: Total market uptake evolution of the years for the different strategic combinations in the basic net neutrality scenario

3.2 Network upgrade under neutrality

The second scenario under study assumes net neutrality but eliminates the congestion, as it assumes the ISP upgrades the network to cope with the higher bandwidth demand. The game matrix with both NPV and market uptake equilibriums is shown in Figure 6, the comparison with the basic NN scenario for market uptake and customer distribution is shown in Figure 7.

		ISP	Network upgrade			
			H		L	
OTT	Net present value	H	€ 1.051.390.686	€ 290.360.501	€ 935.398.458	€ 287.445.109
		L	€ 982.686.532	€ 308.098.970	€ 874.747.778	€ 314.365.057
	Percentage of customers	H	27,52%	20,12%	35,80%	19,49%
		L	22,21%	33,08%	29,99%	32,94%

Figure 6: The game matrix for the network upgrade scenario shows the same equilibriums as for the basic NN scenario

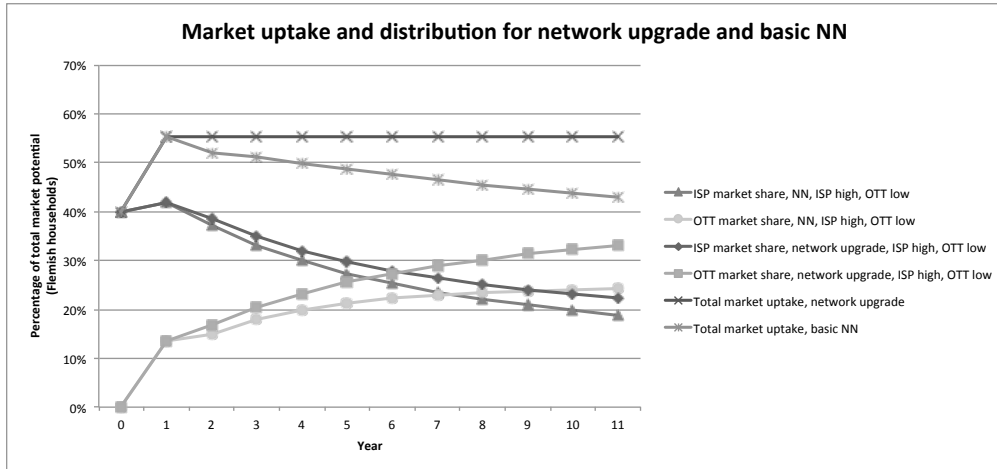


Figure 7: Total market uptake and customer distribution evolution for the network upgrade and basic NN scenarios, strategic combination ISP high, OTT low

Because of the network upgrade, the total market uptake will increase. This has an impact on the NPV outcome for both players: the NPV for the ISP will be slightly lower because of the investment in the network upgrade, while the NPV for the OTT will be slightly higher because of the higher customer uptake. The NPV for the ISP is still positive, we can thus assume that its current market share is sufficient to pay back the network investment.

Because of the absence of congestion, this scenario retains the full customer base. The Nash equilibriums however do not change in comparison to the basic NN scenario. From comparison with the basic NN game matrix can be concluded that the ISP under net neutrality regulations will rather drop its price than invest in the network, since that strategy will lead to a higher NPV.

3.3 Service access fee

In this scenario, the ISP will install DPI equipment to identify OTT customers and charge them an extra fee of 10% on top of the VOD subscription fee. The bandwidth is, as in both scenarios above, still evenly shared among players. The game matrix can be found in Figure 8.

The game matrix logically returns the same HL strategic combination as Nash equilibrium. A higher price results in higher service access fees and reduces the price difference between the ISP and the OTT. Therefore, the ISP will not only retain more customers, but will also recover revenue from the OTTs customers. A lower price will, however, provide a greater increase in the overall market, but it already became clear from the basic network neutrality scenario that this increase in customers does not outweigh the price difference.

		ISP	Service access fee			
			H		L	
OTT	Net present value	H	€ 1.191.852.634	€ 196.722.368	€ 1.072.343.755	€ 205.947.437
		L	€ 1.194.033.519	€ 215.630.739	€ 1.089.764.884	€ 218.121.856
	Percentage of customers	H	22,27%	12,14%	28,75%	12,43%
		L	19,98%	20,62%	27,35%	20,95%

Figure 8: The game matrix for the service access fee scenario shows again the same equilibriums as for the basic NN scenario

3.4 Dominant ISP

This scenario starts from the assumption that the legislation does not impose neutrality. The ISP can thus distinguish data streams by installing DPI equipment. Here, the ISP asserts his power and dominates the OTT by favoring its own customers. This practice increases the congestion for the OTT customers, while the congestion for the ISP remains minimal.

		ISP	Dominant ISP			
			H		L	
OTT	Net present value	H	€ 1.320.421.073	€ 19.734.323	€ 1.278.335.833	€ 21.114.313
		L	€ 1.323.236.869	€ 25.564.414	€ 1.278.577.162	€ 27.797.184
	Percentage of customers	H	30,87%	0,00%	42,96%	0,00%
		L	30,87%	0,00%	42,96%	0,00%

Figure 9: The game matrix for the dominant ISP scenario shows a disastrous outcome for the OTT

The results of the game matrix still show the same equilibriums, but now show an extreme outcome in terms of market uptake (Figure 9). This can be explained by the amount of congestion the OTT experiences from the second year onwards, which is a consequence of the assumption of a fully saturated at the start of the study period. Once the OTT comes in, the market potential will grow due to the lower average price and the saturated market will become congested (Figure 10). As the ISP gives priority to its own customers, there is no more bandwidth left for the OTT to use. As a result, the customers of the OTT will receive an offer of unacceptable quality (very high congestion cost) and will unsubscribe or join the ISP. This scenario thus results again in a monopoly position for the ISP.

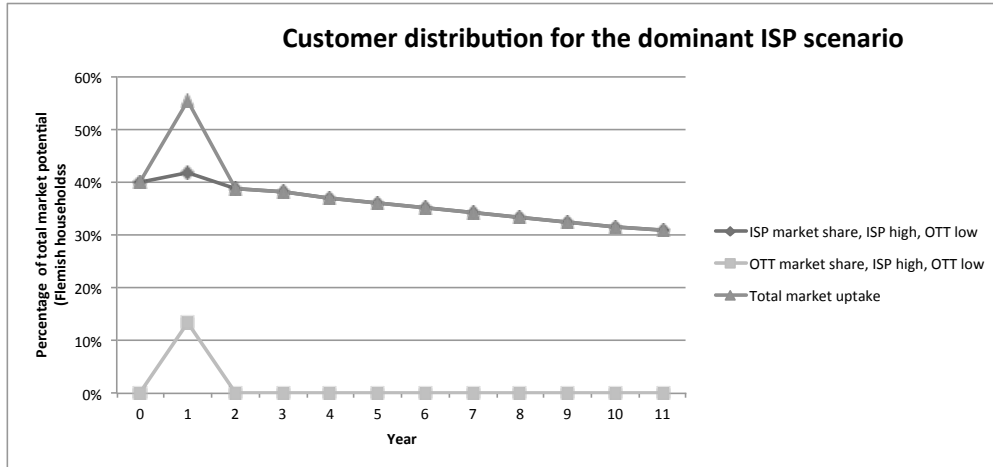


Figure 10: The customer distribution evolution shows that in the dominant ISP scenario the market will evolve again to a monopoly

3.5 Preferential Distribution Fee

The fifth and final scenario is characterized by the creation of a “fast lane”. The ISP divides the available bandwidth into two lanes. The first lane (containing 50% of the bandwidth) will be used for normal best-effort traffic, while the second lane (managed lane, also 50% of bandwidth) will be used for those customers that pay an additional fee. In order to distinguish between customers, the ISP again installs DPI equipment. The OTT has the choice to also offer its customers a preferential treatment, for the same price as the ISP. However, in case the managed lane is congested, the ISP customers will get service first.

		ISP	Preferential distribution fee			
			H		L	
OTT	Net present value	H	€ 1.154.490.248	€ 208.213.369	€ 1.039.290.101	€ 211.194.350
		L	€ 1.119.388.953	€ 226.237.385	€ 1.020.795.568	€ 237.701.821
	Percentage of customers	H	19,74%	12,03%	25,95%	12,12%
		L	17,63%	21,10%	24,48%	21,98%

Figure 11: The game matrix for the preferential distribution fee scenario again shows the same equilibriums

The game matrix (Figure 11) shows little impact on the outcome for both players. The increased congestion for the “normal” customers has a – limited – negative effect on the total market uptake.

3.6 Comparison of all scenarios

After having studied all scenarios separately, this section compares the equilibrium outcome for all of them. Figure 12 shows the results for both the NPV and the market uptake targets, where again the Nash equilibrium is indicated in grey, the Pareto equilibriums in bold.

	Net present value with strategy set HL (in million euro)		Percentage of customers with strategy set LL		Total percentage of customers after 10 years
	ISP	OTT	ISP	OTT	
Basic net neutrality	€ 1.131	€ 255	25,67%	24,31%	49,98%
Network upgrade	€ 982	€ 308	29,99%	32,94%	62,93%
Dominant ISP	€ 1.323	€ 25	42,96%	0,00%	42,96%
Service access fee	€ 1.194	€ 215	27,35%	20,95%	48,30%
Preferential distribution only ISP	€ 1.164	€ 178	29,46%	16,20%	45,66%
Preferential distribution both players	€ 1.119	€ 226	24,48%	21,98%	46,45%

Figure 12: Nash and Pareto equilibriums results for all scenarios

If the ISP is left a choice of scenario, he will pick the dominant ISP scenario. The equipment cost for DPI installation is insignificant in comparison to the increase in VOD income and hence easily paid by the ISP. The dominance of the ISP will make the OTT leave the market. From the perspective of the regulator, this is by far the worst scenario: the scenario returns to a monopoly market while the regulator wants to stimulate and preserve competition.

The strategic combination of prices is the same in each scenario. The ISP will stick to the high price because of its high initial market share, while the OTT will choose a low price to attract more customers. Performing sensitivity analysis however shows that a decrease of initial market share by 14% can change the strategy to LH (ISP low, OTT high, see further).

If DPI equipment is prohibited (thus if net neutrality is obliged by law), the ISP will not upgrade its network if he is only interested in maximizing its short-term NPV. However, the results of the network upgrade scenario show that the ISP can easily pay the upgrade investment using the revenues from its current customer base. Furthermore, if the ISP adopts a longer-term strategy, they will shift to a low price strategy in order not to lose too many customers.

3.7 Sensitivity analysis

From the discussion of the results obtained above, it is clear that, although general trends will remain the same, some results strongly depend on the used parameters for the case and specific assumptions made. This section will therefore shortly

describe the results of some sensitivity studies, where the values of dedicated parameters were varied to investigate the impact on the overall result.

3.7.1 Price

Variations in VOD subscription fee of both operators led to the following results.

First, the price of the ISP is varied, while keeping the price of the OTT constant (low). A decrease in ISP pricing leads to no changes in the Nash equilibrium, as the ISP will always take the highest price in comparison to the fixed OTT price. An increase in ISP price, will shift the Nash equilibrium to HH as soon as the ISP price reaches €276. At this moment, the difference between ISP and OTT price is again significant enough to make the OTT gain all free customers.

When varying the price of the OTT, assuming a fixed ISP price (both high and low), the analysis shows an optimal price setting for the OTT: the price in which the latter still attracts all customers and gains maximal profit from each customer. Increasing this optimal price will lead to a lower amount of customers, decreasing it leads to a lower profit per customers. The optimal price for the OTT is approached equal to half of the ISP price.

3.7.2 Initial market shares

When decreasing the initial market share of the ISP (assuming the OTT is already present on the market), the strategic combination will shift to HH (ISP high, OTT high) if the ISP only has an initial market share of 93% instead of 100%. When its initial market share is assumed to be 85% or lower, the Nash equilibrium shifts to LH: the ISP will assume a low price to attract more customers, while the OTT gains sufficient revenue from the customers that already subscribed.

3.7.3 Congestion cost

Varying the congestion cost will have an impact on the total available market (market growth or decline). However, varying the congestion cost between 50% and 200% of its original value (exponential function depending on available versus needed bandwidth, see section 2.1) does not change the equilibriums. Increasing the congestion cost to 200% will lead to a decrease in market share of about 16% for both players, lowering the congestion cost to 50% leads to an increase in market share of 8% and 15% for the ISP and OTT respectively.

4 Conclusions and future work

The concept of net neutrality does not allow ISPs to differentiate the traffic on their network. Both proponents and opponents of net neutrality have valid arguments, and regulatory discussion seems to lead to different results in different parts of the world. In general, ISPs are opponents of the net neutrality laws; they argue that the

increasing bandwidth demands of OTT applications are growing beyond their ability to invest in new networks. As a result, they want to block or throttle certain bandwidth-hungry applications to keep their networks free of congestion. The proponents of net neutrality are the OTT providers: they believe that the ISPs have no right to manage the network traffic based on content, source or destination, and furthermore argue that the ISPs can easily pay their network expansions using the revenues they gain from their Internet subscriptions.

Based on recent discussions in net neutrality lawmaking, this paper identified five scenarios that were evaluated using a combination of a market model and game-theoretic approach:

- **Basic Net Neutrality:** this is the current network with a NN obligation. The ISP will not upgrade his network, which results in congestion problems as applications require more bandwidth over time.
- **Network upgrade:** the ISP invests in upgrading its network upgrade to get rid of congestion.
- **Service access fee:** the ISP installs DPI equipment to identify OTT customers and charge them an extra fee.
- **Dominant ISP:** by installing Deep Packet Inspection (DPI) equipment, the ISP can give his customers all the bandwidth they need and leave only the remainder to the OTT customers, resulting in massive congestion for the latter.
- **Preferential distribution:** the ISP uses half of his bandwidth capacity to create a fast lane on his network. Customers who are willing to pay the preferential distribution fee receive access to this fast lane. Normal customers will suffer more congestion.

The results of the analysis showed that, under the assumptions made for the analyzed case of competition between Telenet and Netflix in the Flemish market, the equilibrium for all scenarios was reached when the ISP assumed a high price and the OTT a low price. Furthermore, the results indicated a strong increase in ISP revenue for all non-NN scenarios, with the dominant ISP scenario even leading to the OTT having to leave the market. When NN is obliged by law and the objective of the ISP is short-term profit maximization, the ISP would rather lower its price than upgrade its network. From the perspective of the regulator, aiming at market uptake maximization, the scenario of net neutrality with network upgrade is preferable.

Future work first of all includes extending the case study to more markets, in order to better underpin the results. Sensitivity analysis can be carried out on more parameters, again to improve the reliability of the results. The offer by both players could be further diversified, e.g. in terms of quality. The game-theoretic model can

also be adjusted. If the game can be made dynamic, where all players can adjust their strategies each year, the dependence of the results on the start assumptions (e.g. 100% of the available market for the ISP in year 0) could be eliminated, as the game can be re-iterated yearly. Finally, the game can be played with more than two market players, both at ISP and OTT side, to evaluate the effect of competition on the ISP or OTT specific markets.

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